

Thoughts on pnn2 inside- and outside-the-box studies

David E. Jaffe, BNL

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Abstract

Some thoughts about outside-the-box studies for the E949 pnn2 results are discussed, in particular, DELC0 vs the kinematic box and $R(PV)$ vs $R(CCDPUL)$. In addition, a proposal for an inside-the-box function using DELC0 is also discussed briefly.

1 Outside

The only documented outside-the-box (OTB) study for the E787 analysis that I've found is the DELC0 2 to 6 ns region in Section 18 of TN-391 [1]. A proposed enlargement of the E787 signal box for E949 is shown in Table 1. If the background is reasonable then the 2-6ns OTB region in E787 will become part of the signal region for E949; if not, it could be used again as an OTB study. Similar comments apply for the extended kinematic box defined in Table 2.

	DELC06	DELC
1997 R,P,E BOX	$A_N \equiv 1$ $B_N \equiv 1$	$A_N \approx 1.19$ $B_N \approx 1.28 \times 1.29$
2002 R,P,E BOX	$A_N = 1.22$ $B_N > 1$	$A_N \approx 1.46$ $B_N > 1$

Table 1: Proposed enlargement of the signal box. A_N is the normalized total acceptance and B_N is the normalized total background. Estimates from TN391 p.85 and p.111. B_N for the DELC cut comprises only the $K_{\pi 2, \text{scat}}$ and CEX backgrounds. The definitions of the kinematic boxes are shown in Table 2. The increase in A_N due to the kinematic box is given in Ref. [2]. The $A_N = 1$ and $B_N = 1$ region is the 1×1 signal box referred to in this note.

	old (TN385)	new
PTOT	(140,195)	(140,199)
RTOT	(12,27)	(12,28)
ETOT	(60,95)	(60,100.5)

Table 2: The E787 and E949 kinematic box dimensions.

R(PV) \times R(CCDPUL)	B	Interval
200×8	1	—
100×4	4	(0,10)
50×2	16	(8,26)

Table 3: A scenario for an OTB study for the $K_{\pi 2, \text{scat}}$ background. B is the background in the 1×1 signal region. “Interval” is the approximate range for a $\sim 1\%$ poisson probability; for example, the probability that a poisson distribution with a mean of 16 fluctuates to 26 or more events is $\sim 1\%$.

Any additional OTB studies in E949 should focus on the expected dominant background due to $K_{\pi 2, \text{scat}}$. From Bipul’s thesis [3] the total $K_{\pi 2, \text{scat}}$ background is $(0.62 \pm 0.17) + (0.394 \pm 0.084) = (1.01 \pm 0.19)$ for the 1996 and 1997 data. The two cuts that target this background are the photon veto (PV) and the CCD pulse-fit cut (CCDPUL). The PV rejection (Table 3.7, Class 17) was estimated to be 163 ± 23 and 187 ± 40 for 1996 and 1997, respectively. The CCDPUL rejection was measured to be 7.74 and 7.41 in the 2/3 samples (Table 3.5, normalization study) of 1996 and 1997, respectively, *before* the DELCO6 cut. In TN385 [4], the CCDPUL rejection *after* DELCO6 was measured to be 13.0 (481/37) on the 1/3 1996 sample. I could not find any other CCDPUL rejection measurements after DELCO6.

In Table 3 I show an OTB scenario based on 1 expected $K_{\pi 2, \text{scat}}$ background event for the E949 data in the 1×1 signal region and rejections of 200 and 8 for PV and CCDPUL, respectively. The expected E949 background is consistent with the E787 estimate and the relative number of stopped kaons in E949 and E787. This table is simply to give an idea of the number of events expected. Since the cuts need to be loosened almost to the limit of $R(\text{PV}) \times R(\text{CCDPUL}) = 1 \times 1$, there are potential problems. One cannot ignore possible background from $K_{\pi 2 \gamma}$ as the PV is loosened as well as K_{e4} and CEX background as the CCDPUL cut is loosened. In addition, the maximum loosening factor is only 16, so the study is only sensitive to gross mistakes as indicated by the “Interval” given in the table. These problems do not preclude this study, just make it more complicated and less conclusive.

DELCO (ns)	$B(K_{\pi 2, \text{scat}})$	$A(\text{DELCO})$	A/B	B_N	A_N
4	0.389 ± 0.116	0.937 ± 0.002	2.41	1.57	1.14
5	0.301 ± 0.095	0.885 ± 0.002	2.94	1.17	1.08
6	0.258 ± 0.085	0.820 ± 0.003	3.18	1.	1.
8	0.208 ± 0.073	0.702 ± 0.003	3.38	0.806	0.856
10	0.177 ± 0.066	0.605 ± 0.003	3.43	0.686	0.738

Table 4: A copy of Table 9 of TN391 with three additional columns. A/B is the acceptance over the estimated $K_{\pi 2, \text{scat}}$ background and should be proportional to signal/background. B_N and A_N are the relative background and acceptance normalized to DELCO = 6 ns.

2 Inside

In the course of this investigation, I was reminded by Table 9 of TN391 that we could define an inside-the-box function for DELCO > 6 ns. Table 4 shows Table 9 with additional columns showing that there is an increase in the signal-to-background ratio as DELCO is increased. I also note that Jim’s studies showed that the CCD pulse-finding efficiency and fake rate plateaus at DELCO = 15 ns or so [5]. To me this indicates that we could have a ‘golden region’ at large DELCO within the pnn2 signal box. The reliability of the background estimate in the ‘golden region’ could be assessed using the same OTB methodology with PV and CCDPUL cut loosening; indeed the ‘golden region’ is part of the 1×1 box.

References

- [1] Bipul Bhuyan, “Analysis of the 1997 data in the PNN2 region”, TN391, 2 May 2003.
- [2] The increase in pnn acceptance was calculated by Wang Zhe. Details are in <http://hep.tsinghua.edu.cn/~wangzhe/e949/Sep16.ps>.
- [3] Bipul Bhuyan, “Search for The Rare Kaon Decay $K^+ \rightarrow \pi^+ \nu \bar{\nu}$ ”, Ph.D. Thesis, 2003.
- [4] M.V.Diwan, Vivek Jain, Jim Frank and Richard Strand, “Pnn2 1996 1/3 analysis Part 1”, E787 TN385 21 July 2001.
- [5] James S. Frank, “Study of the stopping target CCD pulse fitting analysis”, E949 Tech note K045, 9 February 2005.